DESCRIPTION OF WAKHAN CORRIDOR VEGETATION LAND CLASSES DELINEATED IN THE SUPERVISED LAND CLASSIFICATION

Wakhi technician setting out transects and establishing plots for standing crop measurements during the 2008 field season.

Table of Contents

List of Tables

List of Figures

List of Appendices

PREFACE

This document provides additional description of the vegetation land classes used in the supervised rangeland classification of the Wakhan Corridor. Information on methodology of the supervised land classification is provided in the report "Land Classification of the Wakhan Study Area." Non-vegetated classes are not discussed in this document as these classes (water, snow, rock, etc.) should be obvious and are presented in the previously mentioned report. For some vegetation land classes community types within the class are also described to provide the reader with additional information on communities within the land class. Descriptions of land classes generally includes information on elevation, slope, plant and site cover attributes such as soil cover, rock cover, litter cover, and vegetation cover attributes and standing crop (kg/ha) by life-form. The report begins with an introduction of the rangelands of the Wakhan Corridor, description of methods for developing land classes that were used in the supervised land classification, and then provides vegetation land class descriptions and community types within the land class descriptions. The information provided, especially standing crop information, should allow land managers to determine if current stocking levels are appropriate for current land class productivity levels.

VEGETATION LAND CLASSES OF THE WAKHAN CORRIDOR

INTRODUCTION

The Wakhan Corridor is dominated by a harsh natural environment where plant growth is generally limited by poor soils, low moisture, a short-growing season, and cold temperatures. Approximately 75% of the area is non-vegetated (Table 1; Figure 1). Rangelands dominate the landscape and have formed over time under the influence of the geology, soils, climate, and associated animals. With the dynamic nature of the environment plant communities are continually changing in time and space.

The mountain landscape of the Wakhan is dominated by steep mountains and associated glacier, high elevation plateaus, steep slopes (with scree slopes prevalent), alluvial fans, and some relatively large valleys. The climate is cold and dry so that these vegetation types are dominated by a cold, semi-desert type at mid and lower elevations and alpine and cushion plant communities at higher elevations below the nival (rock and ice) zone[1] where ice formation and frost heaving of soils may impact plant communities. "Green strips" and meadows form where there is additional water from melting glaciers, along streams, and sub-irrigated areas. Soils are generally poorly developed, and as associated with the mountain building processes, are relatively young soils with little horizon development.

No weather stations exist in the Wakhan so estimations of annual precipitation have been based on surrounding stations in Pakistan, Tajikistan, and Afghanistan. Frietag (1971) provides precipitation map for Afghanistan which shows the Wakhan with precipitation belts of 200 mm to 400 mm (western lower portion and low elevation areas), 600-1000 mm for high mountains, 400-600 mm for most of Little Pamir, and 200-400 mm in the lower corridor. It is likely that the lower valley may receive as little as 100 mm based on vegetation type. From vegetation condition and type the precipitation "belts" suggested by Frietag (1971) appear to be on the high side. It is also likely that some of the wide "upper valley floors" are impacted by "rain shadows" and likely receive less than 200 mm of precipitation. In the higher mountains precipitation may approach the 600-1000 mm precipitation zone as shown by Frietag, but most of this precipitation

[1] Breckle (1971) describes the nival zone as occurring at 4900 m on northern exposed slopes and 5300 to 5400 m for southern exposed slopes in northern Afghanisan. This seems to be accurate for much of the Wakhan.

occurs in snow/ice zones with little vegetation. The majority of the precipitation occurs in winter and spring with summer drought. It is likely that much of the snow in lower areas sublimates, compounding semi-arid conditions.

Table 1. Land types for Wakhan study area.

Land Type	**Area (ha)**	**% of Area**
Barren (Areas Classified As No Vegetation)		
Bareground/ Alluvial Fans	442101	44.14
Rock/Shadow	3322	0.33
Rock	138385	13.82
Salty/Baresoil	3104	0.31
Total Bareground/Rock	586912	58.6
Snow and Ice	143300	14.31
Ice/Rock (glacier edge)	1090	0.11
Snow/Glaciers	144390	14.42
Water	4828	0.48
River	2687	0.27
Lake Ice	6696	0.67
Rock/Water (river side)	5040	0.50
Water	19251	1.92
Clouds	1017	0.10
Total Barren (non-vegetated)	751570	75.03
Vegetation Type (Class)		
Ag-Forest-Pasture Mix	4760	0.48
Forest Shrub Mix	492	0.05
Wet Meadow	16942	1.69
Sedge Meadow	16089	1.61
Salt Grass	8270	0.83
Artemisia Steppe	37919	3.79
Artemisia Cold Desert * (subshrub)	48367	4.83
Low Sage	32536	3.25
Cold Desert	6540	0.65
Cold Desert Slopes	13317	1.33
Alpine Grass	40898	4.08
Alpine Forb	23944	2.39
Total Vegetated Areas	250074	24.97
Total Land Area	**1,001,644**	**100.00**

* The *Artemisia* cold desert land class was renamed to *Artemisia* subshrub land class in this report.

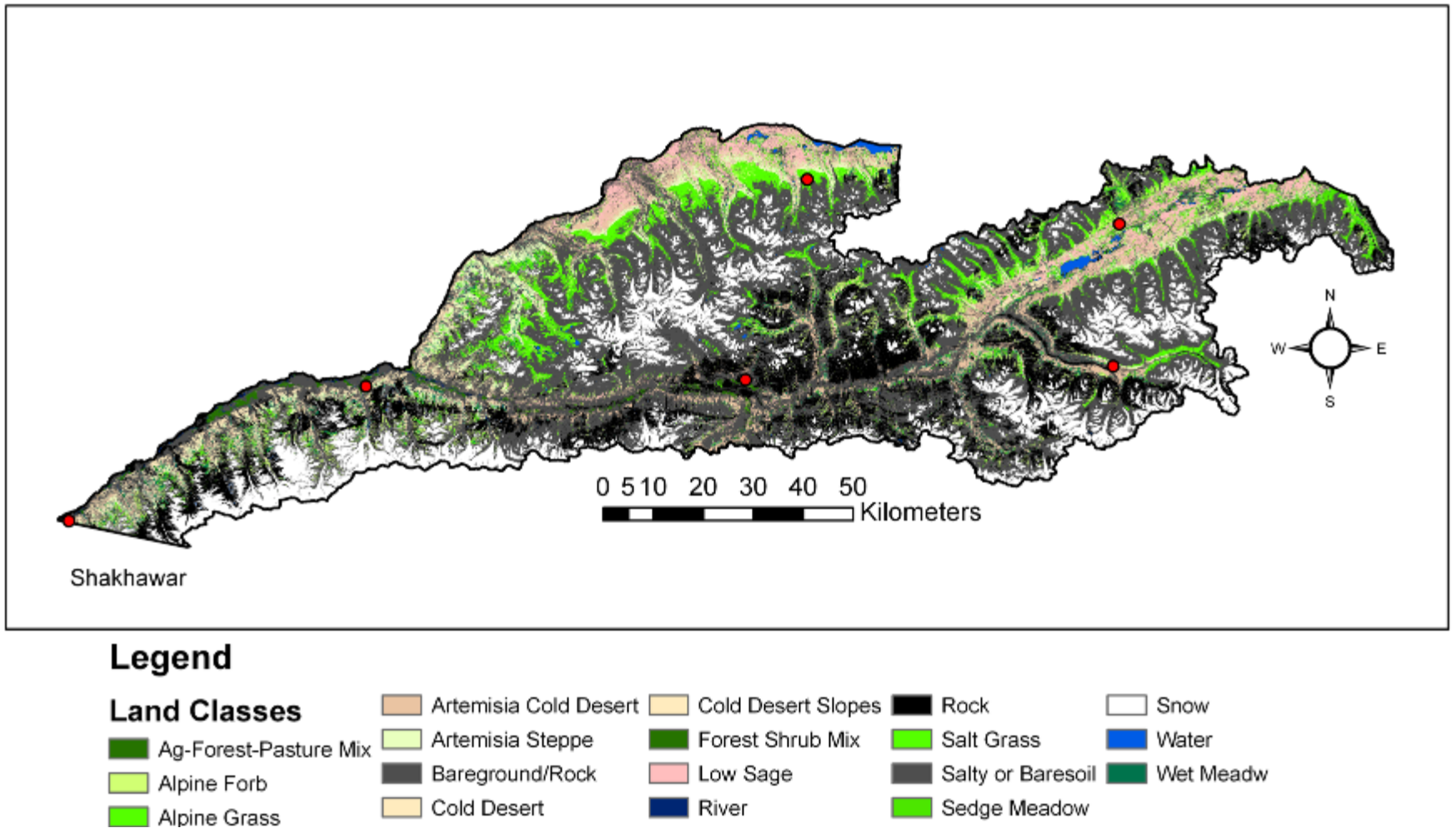

Figure 1. Land types designated for the Wakhan rangeland analysis area developed previously with a supervised classification.

Altitude is an important factor in plant community development for a number of reasons. In higher altitudes the growing season is shorter, frosts frequent, solar radiation is more severe, and snow and total precipitation are greater. Aspect (sun angle) and degree of slope interact with elevation to influence vegetation with south and west aspects being warmer/dryer with lower vegetation cover and production. Also, at the higher vegetated elevations in the Wakhan, human use is less as these areas are more difficult for human habitation because of colder weather. In general these areas are less impacted by livestock, but in certain areas livestock use is significant to the nival zone. The influence of soil frosts can be seen as "frost heave" and thus lower plant cover, especially in the upper alpine region between 4500 to 5000 m.

The potential values of different rangelands is largely associated with their plant communities and as such different rangeland types are characterized/named associated with physical site characteristics (soils, precipitation, geographic area, etc.) and/or plant communities. Petocz (1975) classified the rangelands to the Big Pamir and Little Pamir into 5 alpine types based on either vegetation or site characteristics. These were a Sedge Meadow, Steppe, Rubble Slopes and Scree, and Heaths and Gulleys. In a previous report on land classification of the Wakhan the WCS rangeland team categorized the Wakhan Corridor into 11 non-vegetated classes and 12 vegetation classes or vegetation types. The area (ha) of each vegetation type, as well as non-vegetated land classes, is provided in (Table 1). In the following sections the vegetation land classes of the Wakhan Corridor are described. The location of land classes is provided in a previous report. These plant community land classes are delineated using predominately vegetation characteristics (dominant overstory and understory species) and to a certain extent elevation. Where other vegetation types were delineated in a vegetation class these types are also discussed.

Methods

The land classification system was developed from Landsat ETM+ images using image processing software (ERDAS Imagine 9.3 from Leica Geosystems) and a GIS of known (target) sites. In this method spectral signatures are developed from specified locations of the image. The process consisted of developing vector layers from field vegetation descriptions for use as training "points" or polygons over the raster scene. The Landsat ETM+ bands used were bands 1-5 and 7, and a "new band" was added which was an NDVI (Normalized Difference Vegetation

Index). Therefore, the classification was developed using 6 "original" bands and the NDVI. The Landsat ETM+ images used for analyses were a 15 August 1999 image (path150/row 34) which included most of the upper Wakhan and a 8 June 2001 image (path 151/row34) used for the lower Wakhan areas to "middle Wakhan" or approximately Sargaz. A 90-meter digital elevation model (DEM) was obtained from USGS (http://gisdata.usgs.net/website/afghan/index.asp) and used to develop slope classifications to illustrate some of the topographic constraints to livestock grazing.

The initial supervised analyses used 14 different "non-vegetated" types and 16 vegetation types for classifying images. Several of the "non-vegetated" types were grouped during subsequent analyses and others were grouped for discussion and for presentation of figures. Of the 16 vegetation types several were also grouped because accuracy was low. For example, initially there were birch forest, cropland, *Salix* shrub, and riverine forest signatures used in developing the classification, but these were later grouped. For example, birch forest and riverine forest were grouped into a "forest/shrub land class". In most areas of the Wakhan the forest communities are small in size and "mixed pixels" common so separation of different types was problematic and therefore these classes were grouped. Other problems occurred in assigning a specific pixel to different signatures. The GPS readings could be off by 5 to 10 meters and there is also error associated with image rectification and as such there is no guarantee that a pixel in the signature file is exactly the same as the pixel on the Landsat image. Evaluation of different land class types generally showed high agreement between the classified file and non-vegetated classes such as water, snow, snow and ice, and rock. Grouping of rock, rock and shadow, and bare-ground was done to improve accuracy. For vegetation types that are similar, accuracy is often low; however, there is often good separation between very different vegetation types. For example, the *Artemisia* Steppe vegetation type and the *Artemisia* Cold Desert vegetation type are quite similar, and it is difficult to determine how accurate the separation of these two types is because even ground data often has both types in close proximity. Also, all Cold Desert vegetation types and the Low sage vegetation type are similar and poor accuracy between types is suspected. Dissimilar vegetation types, for example, sedge meadows (either the

sedge meadow or wet meadow vegetation type) and cold desert types (low sage, cold desert slopes, or cold desert shrub) would generally not be misclassified[2].

The WCS rangeland team established 242 transects where ground cover, plant cover, and physiographic attributes (elevation, slope, aspect) were measured. These sites were used in developing vector layers for the "training signatures" as described above and are used to describe vegetation land classes and community types. At each transect the starting point direction and coordinates of the starting points of transects (end points were also recorded on about 2/3 of the transects) were also recorded. All sites were photographed by taking landscape and close-up photos along each transect to allow all sites to be used as monitoring sites. Physiographic or site factors presented in tables and appendices are elevation (m) and slope (%). Aspect was measured at each transect but this data is not presented, but is included in previous reports.

Plant cover (as canopy cover, foliar cover or basal cover) or ground cover (litter, rock, or bare ground) was recorded using a point technique at each meter mark during 2007. In 2006, basal and foliar cover were determined using a point intercept method and canopy cover was determined using line intercept methodology. Point and line intercept methods were used in 2006-07 to reduce problems in plant identification for the Afghan technicians. The line-intercept method was used to provide additional information on species coverage and composition as many sites were over 85% soil/rock. In 2008, cover was estimated in 0.5 m^2 plot frames by the WCS rangeland team leader as Afghan technicians were not available and it was determined that this would be the most efficient way to supplement plant community information. In *Carex* meadows and for some other communities in which individual plants were not easy to discern, only the point sampling procedure was used. In general two transects were used to characterize site conditions at each site. Transects were generally 50 m long and were spaced 10 m apart.

In this report the vegetation coverage values using a canopy cover measure are reported by life-form: shrubs, sub-shrubs (mostly cushion species), grasses, legumes, Lamiaceae forbs (mints), other forbs, trees/*Salix* (Salix is Salix shrubs and these were not included in the previous shrub grouping) and total values. Foliar cover and basal cover total vegetation values and "basal cover" of rock and litter are also presented. For basal cover methodology rock, soil, litter and total vegetation sum to 100%. Statistical information (mean, maximum, minimum, and standard

[2] Accuracy estimates have not been completed and will be completed and added to the final land classification report.

deviation) and sample size are presented for land classes as appendices. Foliar cover and basal cover values by life-form are not presented. However, presented in Table 2 is a summary of canopy cover, foliar cover, and basal cover means by life-form to illustrate the relationship between different measures. As would be expected canopy cover is highest and basal cover the lowest of the cover measurements. Basal cover varied from 0 to 40% with 31% of transects with 2% or less basal cover. Foliar cover, a measure of the ability of the vegetation to protect the soil surface from raindrop impact, varied from 0 to 96% (the high value a productive sedge meadow and also an outlier as the next highest value was 69%) with 51% of the transects with 10% or less foliar cover. Canopy cover by life-form is presented as canopy cover values have fewer 0s and provides information on the ability of life-form to dominate (higher values suggest that life-form having a competitive advantage or using greater resources).

Table 2. Comparison of canopy cover, foliar cover and basal cover across all transects (standard errors).

Cover Variable	Canopy Cover %	Foliar Cover %	Basal Cover %
Shrubs	5.8 (0.58)[1]	3.0 (0.38)	1.2 (0.20)
Sub-shrubs	1.2 (0.20)	1.0 (0.18)	0.8 (0.16)
Forbs	7.1 (1.01)	4.2 (0.70)	2.1 (0.38)
Carices Dryland	2.3 (0.48)	0.4 (0.13)	0.0 (0.03)
Carices Wetland	8.6 (1.76)	2.6 (1.01)	1.1 (0.45)
Grass	12.6 (1.3)	4.3 (0.55)	2.1 (0.27)
Tree	1.3 (0.66)	1.1 (0.62)	0.2 (0.07)
Total	36.8 (2.0)	16.5 (1.38)	7.4 (0.69)

[1] Standard errors.

For the majority of transect sites measured in 2007 and 2008 standing crop by species was determined to provide an estimate of forage production and productivity of these communities on a dry weight basis. A total of 4 or 6 plots ($0.5m^2$) were clipped at each transect site in 2008 and 2007, respectively. For each plot vegetation was separated by species, placed in paper bags, weighed (green weight) and later air-dried for calculation of weight on a per hectare basis. Data is reported by life-form groups: shrubs, grasses, Carices[3] , forbs and total. Statistical information (mean, maximum, minimum, and standard deviation) and sample size are provided in appendices. Standard deviation is calculated by transect site (all plots for a transect site are

[3] Carices are divided into dryland type (DL) and wetland types (WL). The DL type are Carices of fine leaves on upland sites and the WL type is mostly larger leaved and larger Carices on more mesic sites, not necessarily wetlands..

used as sample values and averaged). As such, on the average a site where n=10 would have approximately 50 plots clipped for standing crop, but the standard deviation (and subsequently a standard error) would be based on a sample size (n) of 10.

As stated previously, a total of 12 vegetation land classes or mapping units were established based on the supervised land classification. These land classes were named: Alpine Grass, Alpine Forb, *Artemisia* Cold Desert, *Artemisia* Steppe, Cold Desert, Cold Desert Slope (same as Cold Desert, but on steeper slopes), Forest-Shrub Mix, Agriculture-Forest-Pasture Mix, Wet Meadow, Sedge Meadow, Salt Grass, and Low Sage. The categorization of these sites was based on development of vegetation classes with all transect sites east of Qila-e-Panja which likely limits accuracy of land classes to the west of Qila-e-Panja. For some land classes little data was available associated with the transect work (for example, the Ag-Forest Pasture Mix which is a mixture of types). Each of these vegetation classes are discussed in the following sections. In each section the land class is described and in some instances different vegetation or community types within the class are described to provide the reader with additional information on aspects of the land class. Initially those classes with the least transect information are discussed. These include the Agriculture Forest Pasture Mix Land Class, the Forest-Shrub class and juniper community types.

RESULTS

Agriculture-Forest Pasture Mix Land Class

The Agriculture-Forest Pasture Mix vegetation type is a complex of crop areas, forests, shrublands, and wet pastures found near communities in the main Wakhan Corridor. No transect data was collected in this type, but many of these areas were mapped on Landsat map sheets during 2008 and used for the supervised classification. The mapping procedure was to use a GPS and map sheets to delineate crop and forest areas, but it was realized that these sites were often intermingled (although forest types are quite small in size). The major plants of cultivated areas included barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), peas (*Pisum sativum*), grass peas (*Lathyrus sativus*) (this plant can cause damage to the nervous system), and vetches were also common (*Vicia* species). It was unknown if the vetches were grown for livestock feed or human consumption or both. In most crop areas several crops would be growing in close

proximity of each other or together. Tree and shrub types would often be associated with crop land borders and this was also true for some wetland pastures. As such, these areas were grouped. Forest and shrub types, some occurring in this land class, are discussed in the following section.

Forest-Shrub Land Class

Trees are uncommon in the Wakhan and are mostly found in valleys along rivers and streams or in villages in the main Wakhan corridor (west of Sarhad-e-Broghil) where there is water and cultivated lands. In the discussion of forest-shrub land class it is stressed that these forest-shrub stands are quite small (generally less than a hectare to a few hectares) and often form very narrow riparian "stringer" communities. Scattered juniper (*Juniperus semiglobosa*) occur in the upper Wakhan, mostly observed between Sarhad-e-Broghil and Langar, but for the most part juniper trees are widely scattered and do not form forest stands or in most cases even an open savannah.

Three forest community types grouped into the forest-shrub land class are described. One is dominated by birch (*Betula*) and willow (*Salix*) shrubs and is found in some of the stream valleys in the Big and Little Pamir. A second forest type is dominated by Salicaceae trees and/or shrubs. In many areas these "forest types" have no or very few trees and are dominated by relatively tall *Salix* shrubs. Often the Salicaceae type occurs as tugai flood plain forest or as associated communities with crop agriculture. *Populus pamirica* is grown as part of local forestry programs and *Salix excelsa and Salix turanica* trees are found near villages and have likely been cultivated to supply building materials. The third "forest community" is the juniper forest type; although, as stated previously these areas rarely form a forest cover and are most generally open savannahs of multi-stemmed juniper of heights of less than 2m.

Salicaceae Forest Community Type

The Salicaceae forest type is a mixture of Salicaceae trees and *Salix* shrubs. The Salicaceae identified in these communities were *Populus pamirica, Salix caesia, Salix excelsa, Salix iliensis, Salix pycnostachya, Salix schugnanica, and Salix turanica.* The major Salicaceae tree species were *Populus pamirica, Salix exelsa, and Salix turanica* (sometimes tree-like). These tree species were found in the main Wakhan Corridor mostly near villages and as such are a part of the Agriculture-Forest Pasture mix land class.

Salix caesi, Salix excelsa, Salix iliensis, Salix pycnostachya, *Salix turanica*, and *Salix schugnanica* are generally shrubs; although, *S. turanica* and *S. pycnostachya* will also grow as a small tree as will others to some extent and these species are present in many forest stands. *Salix schugnanica* was the tallest *Salix* found at higher elevations. The *Salix* shrubs were generally found below about 4100 meters with one exception. A dwarf *Salix* sp., possibly *Salix caesi,* was found in higher elevation valleys to about 4500 m. All of these *Salix* species are likely used by local people for making baskets and these shrubs are used as browse by livestock and wildlife.

Tall-Salix Riparian Community Type

Salix iliensis, Salix pycnostachya, Salix schugnanica, and Salix turanica formed streamside communities in the Wakhan and Pamir river flood plains and in some of the lower stream valleys entering the river systems. In general, these shrub types were small in size especially in the upper Wakhan areas[4] below 3900 meters. It is unknown if the small size of many of these communities was associated with few areas having site conditions for growth of shrubs or if livestock grazing was limiting the establishment of shrubs. In general, it is hypothesized that the habitat for these *Salix* communities is limited, but there is no doubt that grazing and human uses are impacting these shrub communities.

Appendix 1a and 1b are photos of two *Salix* communities. Appendix 1a is a *Salix schugnanica* type found along the Pamir river. Appendix 1b shows a heavily grazed *Salix* community where the shrubs are tree-like. Only two *Salix* riparian communities were sampled and no standing crop data was collected as the sites were heavily grazed. Mean cover values are presented in table 3. For these two sites canopy cover of *Salix* was only 5% and there is no doubt that potential canopy cover of some *Salix* community types should approach 100%; although, these types were quite variable in species and cover. Potential herbaceous above-ground production is hypothesized to be quite variable depending on site conditions and is estimated at 1500 kg/ha.

Birch/Willow Forest Community Type

A birch/willow forest community type (*Betula chitralica*, *Salix schugnanica* and *Salix* sp.) exists as small, narrow and isolated riverine forest types along several streams (especially

[4] Upper Wakhan is referred to as areas outside of main corridor. The main corridor are those areas along the Wakhan river valley from Sarhad-e-Broghil to about Qila-e-Panji and all lower valley areas west of Qila-e-Panji.

streams entering into the Wakhan River) from east of Sharhad-e-Broghil to Langar. These birch/willow communities are found around seeps on north facing hillsides south of the Wakhan River in this area. Only one transect pair was established in the birch/willow forest community type so there is not sufficient data to describe these communities in detail. It was difficult to establish transects in this community type because of the thickness of the trees and shrubs. Also, in cases where these communities were more open, the open character was associated with human impacts (cutting of trees and shrubs or intensive grazing). In spite of heavy livestock grazing and human impacts many of these sites still have a diverse plant community, provide significant cover and shade, and have water available making them important sites for conservation.

The major overstory dominants are *Betula chitralica* and *Salix* species. A shrub understory is generally present with species of *Rosa, Salix, Ribes villosum, and Lonicera.* In some areas *Juniperus semiglobosa* was an associated tree on adjacent dry slopes as well as the shrub *Tamaricaria elegans*. Common grasses included *Calamagrostis sp., Elymus,* and *Poa* species. Some forbs observed in these communities included *Swertia lactea*, *Lloydia serotina*, *Saxifraga hirculus*, *Pedicularis* sp., *Silene* sp., *Cicer macracanthum*, *Plantago* sp., *Ranunculus* sp., *Geranium collinum*, *Gentiana* sp., *Inula rhizocephala*, *Carum carvi*, *Cortia papyracea*, and *Tetratoenium Olga*, *Epilobium angustifolium*, *Potentilla* sp. as well as others. Some harvesting of birch was in evidence (cut stumps used for building material and fuel wood) and willow (apparently for fire wood).

The birch/willow forest site measured was at 3491 m in a relatively deep draw (Appendix 2a). The site was very rocky and little understory vegetation was present as livestock apparently were rested in this area as it was a major camping area between Langar and Sarhad e Broghil. Canopy cover of birch and willow averaged 42% and 27%, respectively (Table 3). Total vegetation canopy cover was 68% and no doubt should approach 100%. Litter cover was relatively high averaging 29%, but basal vegetation cover was only 3%. As stated previously this was a rocky site with rock cover averaging 50%. On other birch/willow sites there was

Table 3. Mean elevation, slope and total vegetation cover measurements (%) (BC = basal cover; FC= foliar cover; CC = canopy cover) and canopy cover (%) of different plant functional groups by land class (LC) or vegetation community type (CT).

Land Class (LC) or Community Type (CT)	Elevation (m)	Slope (%)	Total CC	Total FC	Litter_BC	Soil_BC	Vegetation BC	Rock	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Tree/Salix
Birch Forest CT*	3491	5	68	55	29	46	3	50	0	2	1	1	0	0	2	65
Juniper Forest CT	3581	20	25	16	13	45	5	50	2	8	1	0	0	0	3	9
Tall *Salix* Riparian CT	3677	2	10	45	64	36	10	0	0	0	5	0	0	0	0	5
Wet Meadow LC	4016	1	94	64	66	40	52	0	0	0	1	92	0	0	0	0
Sedge Meadow LC	4311	3	76	37	24	55	39	2	0	0	4	65	3	0	4	7
Degraded Sedge Meadow CT	4227	5	50	49	17	43	33	3	0	0	3	33	9	0	5	0
Salt grass LC	3987	2	59	19	42	75	14	3	0	0	57	0	0	0	1	0
Artemisia Steppe LC	4229	11	36	27	11	61	18	15	1	7	10	2	8	4	6	0
Artemisia Sub-shrub LC	4200	7	24	23	7	73	16	12	6	8	4	3	3	0	1	0
Low Sage LC	4070	7	16	7	2	80	4	14	0	7	6	1	0	0	1	0
Cold Desert (Kralan ct) LC	3948	11	14	6	6	84	3	11	1	8	5	1	0	0	0	0
Cold Desert (*Artemisia* ct) LC	4086	10	21	14	6	70	8	22	1	7	6	7	0	0	0	0
Alpine Forb LC	4462	19	47	28	16	48	21	18	0	0	10	3	9	1	23	0
Alpine Grass LC	4488	9	32	33	16	50	22	21	0	0	10	3	3	1	15	0
Fescue Grass CT	4268	16	47	14	28	87	8	5	1	1	33	2	6	0	5	0

* The birch forest, juniper forest and tall Salix riparian community types comprised the Forest-Shrub land class.

much greater understory vegetation and less rocky substrate around the birch. No standing crop data was collected because all of these sites had very heavy grazing levels. Potential above ground annual production of herbaceous species is estimated at 1200 kg/ha, but would vary greatly associated with site characteristics (soils, percentage of rock, etc.) of this type.

Along the upper Wakhan River between Sarhad-e Broghil and Langar there are a few areas of"side-hill" birch communities on north facing slopes near springs, but again these are uncommon and small in area (Appendix 2b). The birches in these areas are mostly less than 5 meters high and very multi-stemmed. In general, the birch is found in protected stream valleys as shown in Appendix 2c. The birch is used as building material and likely used as fuel at times. The maximum elevation where birch was found was about 3700 m just below Langar on the Wakhan River. *Salix* was always found as an important component of the birch-willow community type.

Juniper Forest Community Type

Scattered juniper (*Juniperus semiglobosa*) occur in several areas of the Wakhan. The majority of juniper sites observed during the rangeland reconnaissance were found between Sarhad-e-Broghil and Langar. In most other areas only a few juniper trees (shrubs) were observed and the plants were very scattered trees or single trees. In the area between Sharhad-e-Broghil and Langar most of the juniper trees are widely scattered and form more of an open savannah rather than a forest.

The rangeland team measured only two juniper sites as this type was uncommon. These sites varied greatly in slope steepness and cover, but the sites were considered representative as it was common to see juniper on flats and also on very steep slopes. The mean values of cover elevation, slope, and cover measurements are presented in Table 3. Mean standing crop values are found in Table 4. However, since only two sites were measured (2 transects/site) the discussion is by individual site as these juniper sites were unique in many ways.

The first of these sites was along a cut-bank about 20 meters above the Wakhan River (Appendix 3). Elevation was 3450 m, aspect 160 degrees, but only a 1% slope. Juniper cover averaged 17% and total plant canopy cover was 37%. Basal area was 7% and rock and litter averaged 44 and 24%, respectively. A second "mountain side" juniper community was measured at an elevation of 3712 m (Appendix 4). This site was on a slope of 40 % and an

aspect of 208 degrees. Juniper was widely scattered and more shrub-like than tree-like. Canopy cover of juniper averaged only 1% cover and total plant canopy cover was only 13%. Basal area of all plants averaged 2% and rock and litter cover were 57% and 2%, respectively. There were signs that juniper had been cut along the main trail, but very few juniper stumps were found so it did not appear that juniper had been a significant component of this areas vegetation during recent times. It is more difficult to determine if the juniper had been more prevalent in the last few hundred years and perhaps removed over time. One would hypothesize that if juniper had been recently cut, for example during the last 15 years one should be able to see remnant stumps, but this was not the case. As reproduction of juniper on these sites appears to be very low (seedlings or small shrubs rare) one must assume that if humans even took a few juniper per hectare the community would digress. It is obvious that the juniper is unique in this area, provides a special habitat not found in large areas of the Wakhan and should be protected. In some areas along the trail fires were started at the base of junipers which will certainly lead to death of the tree (Appendix 5). Above these sites at a very rocky outcrop, juniper was more prevalent and perhaps "seeded" these sites. juniper can be seen from approximately Daliz Pass (3973 m) to just west of Langar along these predominately south facing slopes and occasionally along benches on the north side of the Wakhan River down to an elevation of about 3525 m.

In both sites where transects were established Ephedra sp. and Artemisia (A. rutifolia, A. persica, and A. vachanica) were common. Other shrubs (Rosa, Rhamnus prostrata, Kochia prostrata, Krascheninnikovia ceratoides, Ribes villosum and Lonicera) are present on Juniper sites but were not found on the transect sites. Along the Wakhan River the juniper sites often had shrubs of Tamariciaceae (Tamaricaria elegans and Myricaria sp.) and Hippophae rhamnoides, and Clematis orientalis. The tall bunchgrass Achnatherum splendens were also seen in some juniper sites. Standing crop was 499 kg/ha on the river juniper site with shrubs and sub-shrubs (including Ephedra) averaging 361 kg/ha and 132 kg/ha, respectively. The second site had a total standing crop of only 54 kg/ha with the majority the standing crop of sub-shrubs and Ephedra. Stipa was the dominant grass, but grass cover and production are both low on juniper sites that were observed. In general, these sites produce little forage for domestic livestock; however, the communities are unique because of the juniper and likely provide habitat for a number of wild species and should be protected.

Table 4. Elevation and standing crop (kg/ha) by vegetation land class type for sites where standing crop was determined (89 sites)*.

Land Class (LC) or Vegetation Community Type (CT)	SITES	ELEVATION (m)	SHRUBS (kg/ha)	FORBS (kg/ha)	UPLAND CAREX (kg/ha)	WETALND CARICES (kg/ha)	GRASSES (kg/ha)	TOTAL (kg/ha)
***Juniper* Forest CT**	2	3589	273	0	0	0	3	276
Wet Meadow	2	3951	0	34	0	1385	90	1509
Sedge Meadow	2	4217	0	64	8	978	54	1104
Degraded Sedge Meadow	2	4227	0	148	12	404	94	658
Salt Grass	3	3987	0	29	0	0	1073	1081
***Artemisia* Steppe LC**	18	4244	174	152	0	0	116	442
***Artemisia* Subshrub LC**	12	4192	65	1	17	0	48	131
Low Sage	13	4056	131	7	11	0	54	203
Cold Desert (*Artemisia* ct)	5	3965	118	0	0	0	50	168
Cold Desert (Kralan ct)	11	3975	120	0	0	0	33	118
Alpine Grass LC	6	4515	0	103	9	31	274	417
Alpine Forb	4	4475	0	437	3	0	85	525
Fescue Grass	5	4085	1	95	0	0	292	388
Mean*	7.8	4153	91.8	86.0	4.4	77.9	133.0	381.0
Maximum	18	4690	552	695	73	1940	1690	1986
Minimum	2	3465	0	0	0	0	0	24
Standard Deviation		207.9	120.4	122.4	13.8	294.5	229.7	348.0
Standard Error		22.0	12.8	13.0	1.5	31.2	24.4	36.9

* Mean, maximum, minimum, standard deviation, and standard error of the mean are for all plots transects (n=89). Each transect had either 4 or 6, 0.25 m^2 plots clipped for standing crop estimates. Of the 89 transects, 5 transects were not assigned to a particular vegetation class.

Wet Meadow and Sedge Meadow Land Classes

There are a number of different sedge (*Carex* sp. and *Kobresia* sp.) dominated communities found in wetter areas throughout the Wakhan. Two broad types were identified as major land classes and are shown in the land class map as the Wet Meadow land class and the Sedge Meadow land class. In this section a third type, a degraded sedge meadow, is also

described. The Wet Meadow and Sedge Meadow land classes are broad groupings of several *Carex* sp. and *Kobresia* sp. dominated communities with high vegetation cover and high productivity. The major difference between the sedge meadow and wet meadow land classes is associated with greater productivity of the wet meadow land class associated with more water and probably less intensive livestock use. These two land classes are the most productive rangeland types in the Wakhan and are located in subirrigated and wetland areas along springs, streams, and other sites with high water tables on relatively flat areas. Often these sites are "boggy" and have a high organic layer (peat) that is often collected and burned by pastoralists. The sedges form a dense sod that is resilient to damage to trampling, but in wetter areas grazing results in hummocky vegetation. In general, the wet meadow and sedge meadow land classes are limited in area, but are widely distributed and no doubt supply significant amounts of forage for livestock.

The sedges (mainly *Carex* and *Kobresia*) are difficult taxonomic groups and no doubt there are several community types within these land classes. Major species, often with high cover, include *Kobresia stenocarpa*, *K. capilliformis*, and *K. pamiroalaica* intermingled with other sedges such as *C. melanantha, C. pseudo-foetida, C. orbicularis,*and *C. songarica*. *Scirpus planifolius, S. pumilus, Eleocharis quinqueflora and Juncus articulatus* were other common sedge/*Juncus* species. Grasses often were a small component of the wet meadows with greater coverage at lower elevation. Some common species include *Phleum alpinum*, *Poa pratensis*, *Poa* sp. *Aloepecurus himalaicus*, *Elymus dasystachys*, *and Deschampsia caespitosa*. *Puccinellia* was found where these sedge meadows became more saline.

Forbs vary with moisture and disturbance but often include *Saxifraga* sp., *Pedicularis* sp., *Primula* sp., *Leontoopodium ochroleucum*, *Taraxacum* sp., *Polypogon* sp. *Gentiana* sp., *Lomatogonium carinthiacum*, *Swertia* sp., *Astragalus* sp., *Oxytropis* sp., and *Potentilla* sp. *Astragalus* can form a dense cover on overgrazed sedge meadows. Shrubs are uncommon and completely missing in most sedge meadows. However, on two sites there was a *Salix* sp., but the plants were no higher than the sedges as they were severely browsed.

A total of 26 transects were classified as a wet meadow or sedge meadow land class with the majority of the sites classified to the sedge meadow land class. Summary site characteristics and vegetation cover variables are presented in Table 3 and Appendices 6-8. Mean elevation of wet meadow land class was 4016 m compared to 4321 m for the sedge meadow land class as the

wet meadow types were found in lower areas with greater water and often the sedge meadow class was found in upper valleys (although often these types could be adjacent to each other in valleys). The predominant canopy cover is over 97% Carices (*Kobresia* sp. and *Carex* sp.) for the wet meadow land class (Table 3 and Appendix 6) and 71% Carices for the sedge meadow land class (Table 3 and Appendix 7). A "degraded" sedge meadow had 66% Carices and greater forbs associated with over use by livestock (Appendix 8). Natural plant cover is hypothesized to be greater than 100% canopy cover and approaching 90% foliar plant cover. These sites should also have high soil litter and organic layer with few or almost no rocks exposed. The soil depth in the sedge meadows averaged 30-50 cm and the surface layer was generally rich in organic matter. On many wet meadow sites there was a thick peat layer. For those sites with very high cover of sedges there was often significant diversity of other plant species although low coverage of these other species.

Mean total standing crop was 1495 kg/ha with 90 kg/ha of grass and 34 kg/ha of forbs for the wet meadow land class (Table 4). The sedge meadow land class averaged 1061 kg/ha with 978 kg/ha of sedges and a "degraded" sedge meadow cover type had mean standing crop of 552 kg/ha (Table 4). These standing crop estimates are from grazed sites, only two sites per type (two for wet meadow, two sites for sedge meadow and two sites for degraded sedge meadow), and do not represent annual above ground productivity because ungrazed sites could not be located. However, in 2006, the rangeland team clipped one sedge meadow type with low grazing use that had a standing crop of 3,600 kg/ha. It is hypothesized that many wet meadow and sedge meadow sites should produce over 3,000 kg/ha of biomass per year, but because of high grazing use these sites likely produce 50% of their potential.

Within the wet meadow and sedge meadow land classes there is no doubt several community types. Two relatively unique types, a wet meadow grass type and a mountain slope sedge community type, are discussed briefly. In some areas near Chaqmaqtin Lake there is a wetland type with a mixture of sedges, rushes, and grasses used for hay production. This type had close to 100% vegetation cover, was very productive with standing crop estimated at 3,000 kg/ha with relatively high amounts of *Juncus* species and grasses such as a *Phleum alpinum*, *Trisetum spicatum*, *Puccinellia* sp (slightly salty areas) and *Alopecurus* sp. Forbs included the same species as found in the wet meadow land class with *Taraxacum* species evident in more heavily grazed areas. This type is grouped with the wet meadow land class.

A second relatively unique community type is a mountain slope sedge cover type, grouped with the sedge meadow land class, which occurs on relatively steep mountain slopes generally near the top of high ridges near permanent ice/snow. This type forms where there is additional water from snow melt and often forms a belt between scree, other alpine types and forms a highly dissected environment of unvegetated to vegetated sites. These sites are often relatively narrow bands but supply a valuable and productive grazing resource estimated at 600 kg/ha, but only two sites were clipped for standing crop estimates. Plant cover is 60-85% with rock cover averaging 20%. The soils are generally shallow 20-30 cm and with greater rock fragments and are susceptible to mass slumping. These communities are dominated by species described for the sedge meadow cover type but there are also a large number of alpine meadow species. Major dominant species include *Kobresia stenocarpa*, *K. capilliformis* and *K. pamiroalaica* intermingled with other sedges (*C. melanantha, C. pseudo-foetida, C. orbicularis,* and *C. songarica*) and many alpine species forbs and grasses. These areas are used extensively by yak and are no doubt used by other grazers.

Salt Grass Land Class

A salt grass land class was identified in several areas of the Big and Little Pamir associated with high salinity and water impoundment for some period of the growing season. This type had the highest mean grass canopy cover of any land class; although, cover was variable. Productivity and species composition of this land class is associated with salinity levels and presence of water. The dominant plant cover is comprised of the grasses *Puccinellia distans*, *Leymus secalinus* and *Hordeum brevisubulatum (ssp. turkestanicum)*. Forbs and shrubs were uncommon, but when present Chenopods were dominant. On some sites the productive and tall grass *Achnatherum splendens* was also present and formed small but productive sites (Appendix 9). A total of 8 transects were classified to the salt grass cover type. Mean site characteristics are presented in Table 3 and additional statistics are presented in Appendix 10. On four sites *Leymus* was the dominant grass, on two sites *Puccinellia* was dominant, and for two sites there were approximately equal dominance by *Leymus* and *Hordeum*. *Puccinellia* appeared to dominate where there was more water or "ponded" water for a greater portion of the growing season and salinity levels appeared high although not measured. *Leymus* sites varied from highly

productive to low productivity, again apparently associated with salinity level and water availability. *Leymus* and *Hordeum* sites were intermediate in productivity.

Two broad vegetation types were identified in the salt grass land class and sampled with transects: a salt grass meadow and a salt grass flat. In the land classification the salt grass land class refers to the salt meadow community type which has greater vegetation cover and productivity. This land class averaged 1081 kg/ha total standing crop but varied from 301 kg/ha to 1690 kg/ha on the three sites where biomass was measured (Table 4 and Appendix 11). Grass canopy cover averaged 57% which is greater than any other land class (Table 3 and Appendix 10). Few forbs, shrubs, sub-shrubs, or sedges were present on sites measured.

As stated previously, these sites showed high variability associated with salt concentration and soil water availability. Some sites have "extra" water associated with "water ponding" whereas other sites have some sub-irrigation, but evaporative demands leads to accumulated salt conditions near the soil surface. The relatively high productivity of these sites is somewhat offset by the relatively low palatability of most of the plant species on these sites.

The salt flat type (with only two sites measured for standing crop) had a standing crop of 103 kg/ha with the dominate vegetation being *Leymus secalinus* with low cover. The low productivity of the salt flat and its overall appearance is similar to the *Krascheninnikovia lanata* cold desert, but with few or no shrubs. In the land classification these areas are likely shown as barren or cold desert types. A similar site that was almost unvegetated, with an occasional *Halogeton glomerata*, *Chenopodium rubrum*, *Suada olufsenii*, or *Salsola collina* present, was observed in several areas, but without *Leymus secalinus*. No transects were established on these sites, but productivity was estimated at 50 kg/ha and it is likely these sites are shown as barren areas in the land classification.

There is also a *saline* meadow community type (no transect data) where high water levels result in high productivity (estimated at 2800 kg/ha). *Pucinnellia* and *Hordeum* are common, but as these sites are very wet and other grasses and *Juncus* and Carices are common. This community type intergrades into the wet meadow land class discussed in the previous section and is grouped into the wet meadow land class. This community was common around several of the lakes in both the Big and Little Pamir.

Artemisia Steppe Land Class

A very widely distributed cover type is the *Artemisia*-steppe land class. This type is dominated by medium high (25-75 cm tall) *Artemisia* shrubs, predominately A*rtemisia Lehmanniana* and *A. vachanica,* commonly found on mountain slopes and wide valleys throughout the Pamir's. *Artemisia rutifolia* and *A. persica* are two other species that are common on coarser soils and often scree like areas within this *Artemisia* steppe land class. During 2007, 31% of all transects had at least 2% canopy cover of these *Artemisia* species. The *Artemisia* steppe land class is important because it is widely distributed, the *Artemisia* species are the most important fuel source for most pastoralists, and has a moderate potential in regards to forage production for livestock and wild ungulates. The *Artemisia* steppe land class is generally found at elevations from about 3700 to 4200 m with variability associated with aspect, slope and soils.

Only one community type is described within this land class: an *Artemisia*/*Festuca-/Stipa* community type. An *Artemisia*/*Stipa* community type likely exists, but the WCS rangeland team did not have sufficient transects to categorize this community type. Soils of the *Artemisia* steppe land class are medium textured (silt loams, silty-clay loams, and clay loams) of medium depth).

Artemisia/Festuca-Stipa Community Type

The *Artemisia*/*Festuca-Stipa* community type-phase includes several communities in which the dominant grass species differ by cover and productivity. As all of these areas are greatly impacted by human uses (livestock grazing and shrub collecting for fuels) and the pristine cover of these sites is very difficult to discern. Perhaps some of the more productive of these sites would be grasslands with low grazing impacts. A *Festuca* grassland community type was identified (see below) that was quite productive and had no sagebrush, but it is hypothesized that the *Festuca* community was a transition type from an *Artemisia* steppe to an alpine grassland. It is also likely that there is an *Artemisia/Stipa* community type, but again with the high variability associated with natural conditions and with heavy human impacts delineating different types of *Artemisia* steppe was not done in this project. As such, the *Artemisia/Festuca* and *Artemisia/Stipa* community types were grouped into an *Artemisia/Festuca-Stipa* community type-phase and thus represents the *Artemisia* steppe land class.

A total of 20 transects were classified into the *Artemisia*/*Festuca-Stipa* community type. A summary of site characteristics and plant cover is presented in Table 3 and Appendix 12. The

dominant shrubs are A*rtemisia Lehmanniana* and *A. vachanica* with other woody *Artemisia* species uncommon. The most productive sites in this community type are found on cooler aspects (north and east) below the alpine communities where species of *Festuca* and *Poa* are dominant grasses. *Koeleria cristata* is also a common species but of low coverage (although in most areas *Festuca* and *Poa* are of relatively low coverage because of grazing impacts). *Stipa* becomes more common on warmer (south and west) aspects and productivity decreases. A comparison of this community type with the *Artemisia*/*Acantholimon* community type (see below) shows that the Artemisia steppe land class has higher grass and forb cover and less *Carex* (dryland sedges).

The *Artemisia*/*Festuca-/Stipa* community type showed significant grazing use and often high cover of unpalatable forbs such as *Potentilla* sp., *Neptea* (*N. pamirensis* and *N. podostachys*), *Astragalus* sp (*Astragalus nivalis* main species), *Oxytropis* sp., and *Dracocephalum paulsenii*. Total standing crop averaged 433 kg/ha (Table 4 and Appendix 13). Total shrub, total forb, and total grass standing crop averaged 174 kg/ha, 152 kg/ha, and 116 kg/ha, respectively. Potential grass productivity of these sites is hypothesized at 450 kg/ha. The current low average grass standing crop was considered an influence of high livestock grazing pressure and reduced productivity. For these sites plots were clipped that generally had little or no current livestock use. Livestock grazing increases "mat-forming" forbs (*Astragalus nivalis*, *Dracocephalum paulsenii*, *Oxytropis* sp.), forbs with high anti-herbivory compounds (*Potentilla* sp. and *Nepetea pamirensis and N. podostychys*), sub-shrubs (*Acanotholimon* sp), and bare ground.

It has been speculated that the *Artemisia* shrub type is a disturbance induced climax (disclimax) in the Wakhan associated with livestock grazing. It is the opinion of the range team leader that *Artemisia* shrubs are the natural dominant overstory of this land class, but the amount of *Artemisia* is often associated with human impacts. No doubt heavy livestock grazing has impacted these communities and in some cases increased coverage of *Artemisia* sp., but in many areas *Artemisia* cover has been reduced associated with its use as a fuel source, especially near villages. These shrubs protect sites by reducing wind flow across the site, reducing soil loss, catching/holding snow, and increasing soil protection and moisture by modifying conditions at the shrub canopy zone. The canopy zone is often an area where grasses and other forage species are protected from intensive grazing. These "protected" forage plants thus may provide the only

seed source for revegetating sites that are more intensively grazed. As such, conservative use of shrubs for fuel is important and removal of all shrubs for a particular area or site should be avoided.

Artemisia *Subshrub Land Class*

An *Artemisia* cold desert land class with low vegetation productivity and cover, but with dominance by *Artemisia* shrubs, instead of *Krascheninnikovia lanata,* occurs on many cold, dry sites. *Krascheninnikovia lanata* is often present but always at low coverage (< 2%). The *Artemisia* dominant overstory is generally the same as the *Artemisia* steppe, but these sites have very low grass cover and greater cushion plants or subshrubs. As such, these sites are likely a grazing disclimax of the *Artemisia* steppe or a transition type to the Cold Desert type described below. The *Artemisia* subshrub land class averaged only 168 kg/ha total standing crop with shrubs comprising 118 kg/ha of this total (Table 4). The *Artemisia/Acantholimon* community type is the main *Artemisia* cold desert type and is discussed below.

Artemisia/Acantholimon Community Type

An *Artemisia/Acantholimon* community type was similar to the *Artemisia*/*Festuca-Stipa* community type, but several sub-shrubs or cushion-like plants were present at relatively high cover levels. No information on standing crop of the subshrubs is available as they were very difficult to clip or determine current season growth. These sub-shrubs were predominantly *Acantholimon* sp. (*Acantholimon erythraeum, Acantholimon gili, and Acantholimon pamiricum*) with some low *Ephedra sp*. A total of 15 transects had at least 3% canopy cover of sub-shrubs. Like the *Artemisia*/*Festuca-Stipa* community type the dominant *Artemisia* is *A. rutaefolia*. A summary of site characteristics and plant cover is presented in Table 3 and Appendix 14.

Grasses were dominated by *Stipa* and *Festuca* at almost equal mean cover and representing 90% of total grass cover. Mean total standing crop was 168 kg/ha, which did not include the thorny sub-shrubs, mainly *Acantholimon*. Shrub, forb, and grass standing crop were 110 kg/ha, 8 kg/ha and 50 kg/ha, respectively. Sub-shrub standing crop was estimated at 80 kg/ha (Table 4 and Appendix 15). As such, these sites produce low forage and browse resource for ungulates. It is also likely that the *Artemisia/Festuca-Stipa* community type could regress to a site with high sub-shrubs and thus these two community types could be easily confused. The WCS rangeland team leader hypothesizes that a "natural" *Artemisia*/*Acantholimon* community

type exists where there is greater rock coverage, coarser soils, and as such the sites are more xeric, but much of the *Artemisia* steppe has likely degraded to the *Artemisia/Acantholimon* community type (*Artemisia* subshrub land class) associated with overgrazing by domestic livestock. This has greatly decreased potential forage production in much of the Big Pamir and Little Pamir and these sites often show evidence of soil loss associated mostly with wind erosion.

Low Sage (Artemisia) Land Class

A low sage land class is a common cold-desert shrub type throughout much of the Little Pamir. The dominant *Artemisia* species is *A. leucotricha*. This shrub is less than 35 cm tall and appears grey or white. *A. rhodantha (A. roxburghaina syn.)* was also common and occasionally found was *A. rutaifolia*. A total of 25 transects (19 %) had canopy cover of at least 2 % of these two *Artemisia* species. On 22 transects low *Artemisia* was the dominant shrub canopy with a mean canopy cover of 7% with a maximum cover of 14% (Table 3 and Appendix 16). Mean elevation was 4070 m. On sites with similar landscape appearance the low sage was replaced by *Krascheninnikovia lanata* and it is hypothesized the *Krascheninnikovia lanata* sites had higher levels of salts in the soils profile.

Stipa was the dominant grass comprising 83% of the grass cover. *Hordeum* and *Leymus* were common, but at very low cover values. A dryland *Carex* sp. was also common on some of these areas, but again at low coverage percentage. Forbs were uncommon with occasional *Halogeton sp*., *Christolea pamirica*, *Xylanthemum pamiricum*, and *Ajania tibetica*. The low sage land class is common in valleys along the Wakhan River and Aksu River in the Little Pamir, but in general these low sage communities are relatively small in area. Soils are shallow, with a low desert pavement appearance and with high course fragments. Signs of salts are common but apparently are not as saline as the *Krascheninnikovia* community type. These sites are droughty and were often in the valley bottoms. .

Total standing crop averaged 202 kg/ha with 131 kg/ha of shrubs, Shrubs were predominately the low sagebrush, but an occasional *Krascheninnikovia lanata* or taller *Artemisia* species were also found. Total grass, total forb and a dry-land sedge standing crop averaged 54 kg/ha, 1 kg/ha, and 11 kg/ha, respectively (Table 4 and Appendix 17). Because of the low community cover and low productivity, these areas are prone to erosion. It is unknown if these

areas should have greater *Krascheninnikovia lanata* and other forage species than currently present; however, on many of the measured sites the areas appeared to suffer from both erosion and grazing/browsing as shown by pedastalled plants and rocks. There is little doubt that these sites are naturally of low productivity, but also have been impacted by livestock grazing which has increased soil loss and decreased forage and browse production.

Cold Desert Land Class

The cold desert land class is represented by sparse cover of chenopod and/or Asteraceae shrubs. In lower elevation areas and to a lesser extent at higher elevations, the cold desert land class often intergrades into barren areas as productivity is very low and bare ground high. The cold desert slope land class is the same vegetation type, but found on steeper slopes (> 20% slopes). At lower elevations, mostly below 3200 m, the cold desert class was dominated by *A. vachanica, Artemisia tecti-mundi*, *A. Lehmanniana* and *Haloxylon griffithii*. At higher elevations the cold desert land class is dominated by either an overstory of many of the same *Artemisia* species or by *Krascheninnikovia lanata*. Herbaceous species are of low coverage and productivity with *Stipa* sp. the most common grasses. Two community cover types exist in the cold desert land class. A *Krascheninnikovia lanata* cover type and a *Artemisia* cold desert cover type. These types are very similar in productivity and cover values but differ in overstory dominant.

Krascheninnikovia lanata Cover Type

Krascheninnikovia lanata occurred with at least 2% canopy cover on 42 of the 242 transects (17%) and for 23 transects *Krascheninnikovia* was the dominant or co-dominant shrub species. *Krascheninnikovia lanata* is often observed near marmot dens and other areas of "fertility" such as herders' camps. It can also be found on dry slopes, areas with higher soil salt levels (flats and "badlands"), and as a co-dominant species adjacent to *Artemisia* and salt grass types forming transition communities. Areas where *Krascheninnikovia lanata* was the dominant shrub were restricted to relatively small areas (less than a few ha), and no large areas where *Krascheninnikovia lanata* was the dominant shrub were observed. This was unexpected as this is a common cold desert type in many areas of Central Asia.

Soils in the *Krascheninnikovia lanata* cover type are generally fine-textured, but rock content can be high on some sites. Signs of salts are common and salinity level is important in

influencing different communities within this cover type. On all sites where *Krascheninnikovia* was dominant or co-dominant shrub the type was designated as a *Krascheninnikovia* cover type. However, with further data collection it is hypothesized that a *Krascheninnikovia*/*Leymus* and *Krascheninnikovia*/*Stipa* community type or phase could be designated.

A summary of site characteristics and plant coverage summaries are presented in Table 3 and Appendix 18 for the *Krascheninnikovia* cover type. For these transects *Krascheninnikovia* averaged 6% canopy cover (maximum 14%) and as some transects were close to herding camps there is little doubt that coverage of *Krascheninnikovia* had been reduced by livestock browsing. *Leymus* was the dominant grass and *Stipa* was the only other common grass (frequency of 20%) and forbs were of low coverage. Total standing crop averaged 189 kg/ha with shrub and grass standing crop averaging 153 kg/ha and 35 kg/ha, respectively (Table 4 and Appendix 19). These sites are not very productive, but supply a valuable browse resource in that *Krascheninnikovia lanata* is a palatable and nutritious shrub. However, the low cover of vegetation results in high potential of erosion. Since *Krascheninnikovia lanata* is a palatable shrub, its coverage has likely decreased from browsing and also possibly from harvesting for fuel. Without exclosures it is impossible to state if this community type has been significantly decreased by human impacts.

Artemisia Cold Desert Community Type

The *Artemisia* cold desert community type is very similar to both the *Artemisia* subshrub land class and the *Krascheninnikovia lanata* cover type. It differs from the *Artemisia* subshrub type as this community type has few subshrubs (*Acantholimon* species). It differs from the *Krascheninnikovia lanata* community type by having little *Krascheninnikovia lanata* and an overstory of *Artemisia* shrubs, predominately *A. vachanica, Artemisia tecti-mundi*, and *A. Lehmanniana*. The chenopod *Haloxylon griffithii* occurred at lower elevations in the most xeric sites. *Scorzonera virgata*, *Scariola orientalis*, *Bromus japonicus*, and *Potentilla bifurca* were relatively common herbs with generally low cover and standing crop. This type had greater cover of dryland sedges and rock cover (Table 3) than the *Krascheninnikovia lanata* community type, but standing crop (Table 4) and other cover values were quite similar.

Alpine Land Classes

An alpine land class was delineated on basis of elevation and species coverage. In general, the alpine land class occurs above 4300 m and is associated with greater cover of herbaceous species and without *Artemisia*[5] shrubs or other shrub species. In the land classification two alpine types were mapped: an alpine grassland cover type and an alpine forb cover type. Alpine areas have high landscape diversity and often relatively high species diversity. There is no doubt that these areas are often critical for a number of wild species, but are also used by livestock and show moderate to high levels of degradation. It is hypothesized that many alpine forb communities are associated with livestock overgrazing, but because of high natural disturbance (such as frost heaving, solufluction, snow field impacts, young soils) natural forb communities also occur.

Alpine Grass Land Class

The alpine grassland land class has moderate productivity and relatively high herbaceous cover. This type has a variety of grasses, forbs, and sedges including species of *Trisetum*, *Piptatherum*, *Poa*, *Festuca*, *Phleum, Aloepecurus, Papaver (P. nudicaule), Saxifraga (S. komarovii, S. hirculus, S. sibirica), Stipa (S. mongholica), Mysotis*, *Anemone, Potentilla (P. gelida), Pedicularis, Oxytropis, Primula, Delphinium (D. brunonianum), Oxyria (O. digna), Taraxacum, Polygonum*, *Nepeta*, *Geranium, Carex sp.*, *Kobresia* sp., several Asteraceae (*Waldhemia* sp., *Aster* sp., *Leontopodium ochroleucum*, *Psychrogeton* sp., *Taraxacum* sp.), several Brassicaceae (*Draba* sp., Chorispora, and *Smelowskia* sp.), several Crassulaceae (*Pseudosedum* sp., *Rosularia alpestrisa*, *Rhodiola* sp. and *Sedum* sp.), Carophyllaceae (*Cerastrium cerastioides*, *Silene gonosperma*), and Lilliaceae (*Allium* and *Lloydia serotina*). Most of these sites had a relatively large cover of forbs but also high grass cover and standing crop.

Mean elevation of the alpine grassland land class was 4546 m (Table 3 and Appendix 20). Grass cover and forb canopy cover averaged 12 and 15%, respectively showing that forbs

[5] Artemisia steppe was found above 4200 m so the designation of alpine was mostly associated with loss of *Artemisia* shrubs as a component of the community and elevation above 4200 m.

were a large component of these sites. Grass standing crop (Table 4 and Appendix 21) averaged 274 kg/ha and was the dominant life-form. Total standing crop averaged only 393 kg/ha as most of these sites showed significant degradation from past grazing.

Alpine Forb Land Class

The alpine forb land class had similar landscape characteristics and species presence as the alpine grass land class, but with much greater forb cover and less grass cover (Table 3 and Appendix 24). Forb standing crop averaged 437 kg/ha which was higher than any other land class. Dominant forbs were several Crassulaceae (*Pseudosedum* sp., *Rosularia alpestrisa*, *Rhodiola* sp. and *Sedum* sp.), Carophyllaceae (*Cerastrium cerastioides*, *Silene gonosperma*), and Lilliaceae (*Allium* sp.). As stated above other common forbs included *Papaver (P. nudicaule), Saxifraga (S. komarovii, S. hirculus, S. sibirica), Potentilla (P. gelida), Pedicularis, Oxytropis, Primula, Delphinium (D. brunonianum), Polygonum*, *Nepeta*, *Geranium, Carex sp.*, *Kobresia* sp., several Asteraceae (*Waldhemia* sp., *Aster* sp., *Psychrogeton* sp., *Taraxacum* sp.), and several Brassicaceae (*Draba* sp., Chorispora sp., and *Smelowskia* sp.). Soil loss associated with water erosion associated with overgrazing by livestock was observed as trailing, mass soil movement, and pedalstalling of plants. Forb communities varied greatly with moisture and grazing condtions.

Festuca Community Cover Type (Transition Phase)

A *Festuca* community type was identified on north facing slopes of the upper Little Pamir. This type was not mapped as a separate land class and is "grouped" in the alpine grassland land class. This community type is apparently a transition from the *Artemisia/Festuca-Stipa* community type-phase (*Artemisia* steppe land class) to the alpine grassland land class found at higher elevations. There are a number of *Festuca* species including *Festuca alaica, Festuca pamirica, Festuca rubra, and/or Festuca valesiaca*. This community type would transition to a *Festuca/Stipa* phase and then into a *Stipa* community type with more xeric conditions (lower elevations or south or west aspects).

There were relatively few transects on this type (n=4) and further data is needed to better document this type. However, this cover type occurred in several areas on moderate north slopes in the Little Pamir and should also occur on similar slopes and aspects in the Big Pamir. Mean

elevation was 4155 m and a summary of site characteristics are shown in Table 3 and Appendix 22. These sites had high canopy cover averaging 40 % with grasses averaging 72.5% of the total canopy cover. Total standing crop averaged 330 kg/ha with grasses averaging 321 kg/ha (Table 4 and Appendix 23). The moderate productivity of these sites would make them important sites for livestock and wild ungulate grazing although the palatability of these *Festuca* species may be low to moderate for many grazers. Other more palatable grasses (*Poa* sp., *Elymus nutans,* and *Koeleria cristata*) were common on many of these sites. Figure 1 is a photo of a *Festuca* community on a north facing slope just west of the mouth of Tegermansu Valley. This site apparently received very low livestock grazing and had one of the highest mean plant cover percentages observed on upland rangelands. It is hypothesized that more sites, in both the Big Pamir and Little Pamir, should have much greater plant cover and productivity based on the site photographed and other ungrazed or moderately grazed sites observed.

Figure 2. *Festuca* community type on north facing slope.
Note high litter on this site which showed no recent livestock grazing use. Photo August 21_2007_1740b.

Stipa Community Type Transition

As stated above there is likely a *Stipa* cover type found on more xeric sites than the *Festuca* community type. At times these two communities can be adjacent to each other and separated by only an aspect change; however, in many cases the *Stipa* community transitions to shrub types. These sites are likely classified into *Artemisia* steppe land class as productivity is similar. The major species are *Stipa caucasica* and *Stipa trichoides* with a grass *Pipthatherum* sp. often present. Only two sites were measured that were designated as a *Stipa* community so the limited data does not allow for delineation of site characteristics. For these sites total standing crop was 177 kg/ha. Figure 2 is photo of a *Stipa* community located in the upper Little Pamir. It is hypothesized that with heavy grazing these sites likely regress to a low sage type or *Artemisia* cold desert type.

Figure 3. *Stipa* community on southeast aspect.
This site was adjacent to a *Festuca* community type on north facing aspect. Photo August 25_2007_0800a.

SUMMARY

The rangelands of the Wakhan have formed associated with the climate, geology, soils, and living organisms. As the area is dominated by mountain formation processes including glacial scouring, frost heave, and soil movement (erosion channels, mass flow) down slope and associated with high winds there is large variability in soils and vegetation communities over the landscape. Sites with large areas of relatively similar soils exists only in a few areas in the upper Little Pamir and Big Pamir, mostly associated wide mountain valleys. Mass soil movement as seen by landslides, flood deposits, and mass wasting is common throughout the area and natural and human disturbance no doubt result in a variable landscape. Because of high variability in landscapes the WCS rangeland team developed 12 relatively broad land classes used in mapping of rangelands using a supervised classification methodology. Some of these land classes also have community types (a more specific vegetation type than the land class) described where data or field observations provided such information.

The land classification shows that 75% of the Wakhan is barren. Areas of cold desert (*Artemisia* cold desert, cold desert, cold desert slopes, and low sage land classes) have very low plant cover and biomass levels where forage production is below 100 kg/ha. *Artemisia* steppe and alpine grassland land classes have moderate productivity, but forage production is still less than 250 kg/ha for these land classes. The most productive types are the wet meadows and sedge meadows, both dominated by Carices. Forage production of these types (3.3% of the total area) is potentially greater than 2,000 kg/ha although current forage production is estimated at approximately 1,200 kg/ha.

Standing crop information provided for each land class should allow for an initial estimation of stocking rates (number of animals per area) and for conditions for different sites (degradation, slope and distance from water should be considered in setting stocking rates). Additional analyses would be desirable to determine how accurate the land classification has delineated vegetative lands classes. Preliminary analyses suggests that dissimilar sites are separated (for example, cold desert versus alpine or sedge meadow), but sites with similar productivity (for example, cold desert versus *Artemisia* cold desert) are often misclassified. If this is the case, where dissimilar sites are accurately separated, this should allow for relatively

accurate productivity estimates and thus stocking rates with consideration of other factors. With the current rangeland GIS slope calculations and distance to water could be used to model stocking rate levels.

The natural environment of the Wakhan, mostly dry and cold, results in large areas of rangeland with very low productivity. These sites have been impacted by livestock grazing but it is difficult to determine the level of land degradation. For more productive sites such as the wetland land class, the sedge meadow land class, the *Artemisia* steppe land class, and the alpine land classes grazing impacts are evident and no doubt decreasing forage production for livestock and wild ungulates. These more productive sites should be areas where land managers concentrate efforts to improve grazing management, use of shrubs, use of peat, and other human impacts that may be decreasing the long term productivity of these sites. Monitoring, development of exclosures (for developing information on potential productivity), off-site water sources to reduce pressure on some riparian site would all be helpful in better analyzing level of degradation of these more productive sites. The impact of use of shrubs for fuel should also receive, including an analysis of reproductive potential of shrubs used for fuels and impacts of shrub harvest on grass survival and soil fertility.

APPENDICES

Appendix 1a. Tall Salix type located along Pamir River (37.0628N, 72.6832E, 3080 m).

Both Salix schugnarica and Salix whilagamani occurred. On this site Populus pamirica was also present but very scattered. Common associated shrubs include Hippophe rhanmoides. Under story dominants varied from wet site species such as Calamagrostis epigen, Poa sp. and rushes and sedges to rocky-dry species such as Ephedra, Stipa, and Achnatherum splendens. The vine Clematis tanguitca is also common.

Appendix 1b.. Overgrazed *Salix riparian community type.*

The Salix was growing more as a tree form, but this may have been associated with cutting of branches and heavy browsing by livestock. Photo July 27,2007-1908. Darya-e Istmotsh 37.2298833N, 72.8257833. 35111m.

Appendix 2a. Birch-*Salix* transect site in creek valley.
This is very minor but very unique type in the Wakhan. These sites are often in narrow stream valleys. Photo September 04_2007_1104b.

Appendix 2b. Birch/willow in background on mountain slope (north slope) and in foreground (stream valley.
Photo August12_2007_1147c.jpg. Approximate location 37.00425; 73.67133 (3505m).

Appendix 3. Juniper transect site on cut-slope above Wakhan River. Photo September 04 _2007_0715b.

Appendix 4. Hillside juniper site with low presence of juniper.
Photo September 04_2007_1427.

Appendix 5. Juniper with damage from harvesting wood and burning the base of the tree.
Photo August 12_2007_0916. Approximate location 37.00499; 73.5999.

Appendix 6. Mean, maximum, minimum and standard deviation of cover values for the wet meadow land class (transects=4).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4016	1	94	64	66	40	52	0	0	0	1	92	0	0	0	0	1
Maximum	4173	2	100	98	80	84	88	0	0	0	2	98	0	0	0	0	4
Minimum	3841	0	88	36	44	0	16	0	0	0	0	86	0	0	0	0	0
Std dev	179	1.2	6.9	25.6	15.7	46.3	37.2	0.0	0.0	0.0	1.0	6.4	0.0	0.0	0.0	0.0	2.0

.

Appendix 7. Mean, maximum, minimum and standard deviation of cover values for the sedge meadow land class (transects=11).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4311	102	3	76	37	24	55	39	2	0	0	4	65	3	0	4	7
Maximum	4609	300	10	96	92	54	94	90	10	2	0	12	90	14	0	14	14
Minimum	4019	0	0	44	0	0	5	6	0	0	0	0	38	0	0	0	2
Std dev	269.0	109.0	3.9	15.6	30.5	17.1	34.5	29.6	3.3	0.6	0.0	3.4	15.1	4.7	0.0	3.8	4.2

Appendix 8. Mean, maximum, minimum and standard deviation of cover values for the sedge meadow land classes for degraded areas (n = 11)..

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4360	9	47	36	32	56	24	4	0	0	12	15	12	1	8	20	0
Maximum	4503	30	75	96	64	96	70	15	2	4	46	33	55	10	30	60	0
Minimum	4042	0	9	8	0	0	2	0	0	0	0	0	0	0	0	0	0
Std dev	173.0	10.2	25.8	34.1	25.2	39.4	24.2	5.3	0.6	1.2	15.2	11.0	18.3	3.0	10.4	21.4	0.0

Appendix 9. Photo of *Achanatherum splendens*, a productive grass, occasionally found in the Wakan often near salt grass types.

Appendix 10. Mean, maximum, minimum and standard deviation of cover values for the salt grass land class (n = 6).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	3987	2	59	19	42	75	14	3	0	0	57	0	0	0	1	2	0
Maximum	4075	3	92	56	82	92	58	12	0	0	92	0	2	0	8	8	0
Minimum	3850	1	36	8	6	42	0	0	0	0	34	0	0	0	0	0	0
Std dev	108	1.0	21.8	19.2	26.3	21.6	22.0	5.3	0.0	0.0	22.9	0.0	0.8	0.0	3.3	3.2	0

Appendix 11. Standing crop (kg/ha) statistics by life-form for the Saltgrass land class (sites = 3).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	3987	0	29	0	0	1073	1081
Maximum	4075	0	84	0	0	1690	1690
Minimum	3850	0	0	0	0	297	301
Std dev	120	0	47	0	0	710	710

Appendix 12. Mean, maximum, minimum and standard deviation of cover values for the *Artemisia* steppe land class (transects = 43).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4229	11	36	27	11	61	18	15	1	7	10	2	8	4	6	17	0
Maximum	4442	28	64	52	42	94	54	66	11	32	32	16	31.3	28	36	54	0
Minimum	3923	1	9.8	8	0	22	0	0	0	0	0	0	0	0	0	0	0
Std dev	135.9	7.1	15.3	16.2	11.4	19.8	12.6	15.1	2.3	7.8	7.3	3.9	9.4	6.9	7.3	13.1	0.0

Appendix 13. Standing crop (kg/ha) statistics by life-form for the *Artemisia* steppe land class (sites = 24).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	4244	169	157	0	0	116	433
Maximum	4419	552	366	0	0	429	785
Minimum	3970	11	0	0	0	33	117
Std dev	144.0	143.3	114.1	0.1	0.0	86.8	191.8

Appendix 14. Mean, maximum, minimum and standard deviation of cover values for the Artemisia sub-shrub land class (transects=59).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4200	7	24	23	7	73	16	12	5	8	4	3	3	0	1	4	0
Maximum	4467	25	58	58	30	96	39	45	16	24	22	35	20	5	10	20	0
Minimum	3887	0	7	6	0	34	2	0	0	0	0	0	0	0	0	0	0
Std dev	146	5.7	11.2	11.8	6.5	14.6	9.8	9.8	3.7	5.7	4.8	5.8	5.6	0.8	1.7	6.1	0.0

Appendix 15. Standing crop (kg/ha) statistics by life-form for the *Artemisia* sub-shrub land class (*Artemisia/Acantholimon* community type (sites = 24).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	4192	65	1	17	0	48	113
Maximum	4322	150	4	66	0	145	200
Minimum	3962	0	0	0	0	6	30
Std dev	144.7	51.7	1.4	23.3	0.0	43.1	60.7

Appendix 16. Mean, maximum, minimum and standard deviation of cover values for the low sage land class (n = 29).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4070	7	15	8	3	79	5	15	0	7	5	1	0	0	0	1	0
Maximum	4257	15	34	24	79	100	15	40	7	16	20	10	1	0	6	6	0
Minimum	3948	0	2	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Std dev	86.7	5.2	7.9	5.4	3.5	13.6	3.8	11.5	0.8	4.2	5.5	3.1	0.3	0.0	1.2	1.3	0

Appendix 17 .Standing crop (kg/ha) statistics by life-form for the low sage land class (sites = 13).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	4056	131	7	11	0	54	202
Maximum	4152	405	74	73	0	179	436
Minimum	3948	16	0	0	0	0	47
Std dev	44.1	107.7	19.8	23.8	0.0	61.6	118.4

Appendix 18 . Mean, maximum, minimum and standard deviation of cover values for the cold desert land class (transects = 23) (*Krascheninnikovia lanata* community type).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	3948	148	11	14	6	6	84	3	11	1	8	5	1	0	0	0	0
Maximum	4140	342	30	40	32	28	100	16.2	32	4	20	26	12	0	0	2	0
Minimum	3657	0	0	2	0	0	56	0	0	0	1	0	0	0	0	0	0
Std dev	124	110	7.0	10.0	7.2	7.1	12.4	4.0	10.1	1.3	4.8	7.0	2.5	0.0	0.0	0.4	0

Appendix 19 . Standing crop (kg/ha) statistics by life-form for the cold desert land class (*Krascheninnikovia lanata* community type) (sites = 11).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	3975	120	0	0	0	33	118
Maximum	4140	253	2	0	0	64	290
Minimum	3887	0	0	0	0	1	0
Std dev	61.9	79.3	0.6	0.0	0.0	21.5	97.6

Appendix 20. Mean, maximum, minimum and standard deviation of cover values for the Alpine grass land cover class (transects=12).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4546	6	29	34	15	47	24	24	0	0	12	2	3	1	11	15	0
Maximum	4718	15	56	56	40	76	39	60	0	0	28	8	10	3	19	28	0
Minimum	4288	1	18	20	4	12	14	0	0	0	3	0	0	0	2	5	0
Std dev	192.6	5.7	12.0	17.0	10.7	19.4	7.7	19.9	0.0	0.0	7.5	3.2	2.9	1.0	5.9	7.0	0.0

Appendix 21. Standing crop (kg/ha) statistics by life-form for the alpine grass land class (sites =5).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	4515	0	103	9	31	274	393
Maximum	4690	0	158	43	133	393	543
Minimum	4345	0	50	0	0	128	228
Std dev	132	0	41	19	58	135	131

Appendix 22. Mean, maximum, minimum and standard deviation of cover values for the Alpine forb land cover class (transects=9).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4462	19	47	28	16	48	21	18	0	0	10	3	9	1	23	34	0
Maximum	4590	24	70	30	26	76	37	34	2	0	24	10	20	4	30	46	0
Minimum	4352	8	30	26	1	16	14	5	0	0	2	0	0	0	8	21	0
Std dev	169.3	8.7	16.5	16.5	9.8	22.9	9.4	16.7	0.5	0.0	7.7	3.4	5.4	1.2	9.9	12.6	0

Appendix 23. Standing crop (kg/ha) statistics by life-form for the alpine forb land class (sites =4).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	4475	0	437	3	0	85	522
Maximum	4490	0	695	8	0	203	897
Minimum	4453	0	248	0	0	8	293
Std dev	19.5	0.0	230.9	4.6	0.0	103.3	327.2

Appendix 24. Mean, maximum, minimum and standard deviation of cover values for the fescue land cover class (transects=9).

Statistic	Elevation (m)	Slope (%)	Canopy cover	Foliar Cover	Litter_Cover	Soil_Cover	Basal Cover	Rock_Cover	Subshrub CC	Shrub CC	Grass CC	Sedge CC	Legume CC	Lamiaceae CC	Other forb CC	Total Forb CC	Salix CC
Mean	4196	228	18	45	17	24	86	8	6	3	2	30	1	5	0	5	10
Maximum	4690	342	25	70	28	66	96	16	15	10	4	52	8	26	0	12	38
Minimum	3945	0	11	25	6	4	74	2	0	0	0	16	0	0	0	0	0
Std dev	221.4	164.1	5.5	13.8	8.3	22.5	8.6	4.4	6.4	3.8	1.7	10.8	2.5	9.2	0.0	5.0	11.9

Appendix 25. Standing crop (kg/ha) statistics by life-form for the fescue land class (sites =4).

Statistic	Elevation	Shrubs	Forbs	Carex DL	Carices WL	Grasses	Total
Mean	4236	0	91	0	0	317	350
Maximum	4690	0	169	0	0	393	398
Minimum	3945	0	17	0	0	235	302
Std dev	318.4	0.24	62.6	0	0	66.3	40.0